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Policy mixes for sustainability transitions: New approaches and insights through bridging innovation and policy studies

Florian Kern[a,*], Karoline S. Rogge[b,c], Michael Howlett[d]

[a] Institute of Ecological Economy Research, Germany
[b] Science Policy Research Unit (SPRU), University of Sussex, UK
[c] Fraunhofer Institute Systems and Innovation Research ISI, Germany
[d] Department of Political Science, Simon Fraser University, Canada

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ABSTRACT

There has been an increasing interest in science, technology and innovation policy studies in the topic of policy mixes. While earlier studies conceptualised policy mixes mainly in terms of combinations of instruments to support innovation, more recent literature extends the focus to how policy mixes can foster sustainability transitions. For this, broader policy mix conceptualisations have emerged which also include considerations of policy goals and policy strategies; policy mix characteristics such as consistency, coherence, credibility and comprehensiveness; as well as policy making and implementation processes. It is these broader conceptualisations of policy mixes which are the subject of the special issue introduced in this article. We aim at supporting the emergence of a new strand of interdisciplinary social science research on policy mixes which combines approaches, methods and insights from innovation and policy studies to further such broader policy mix research with a specific focus on fostering sustainability transitions. In this article we introduce this topic and present a bibliometric analysis of the literature on policy mixes in both fields as well as their emerging connections. We also introduce five major themes in the policy mix literature and summarise the contributions made by the articles in the special issue to these: methodological advances; policy making and implementation; actors and agency; evaluating policy mixes; and the co-evolution of policy mixes and socio-technical systems. We conclude by summarising key insights for policy making.

1. Introduction

It has long been acknowledged that a combination of technology push and demand pull instruments is recommended for stimulating innovation (Di Stefano et al., 2012). In addition, systemic instruments have been proposed to complement more traditional innovation policies (Borrás and Edquist, 2013; Smits and Kuhlmann, 2005; Wieczorek and Hekkert, 2012). Moreover, studies on mission-oriented policies (Foray et al., 2012) have argued for policy mixes rather than single policy instruments (Schot and Steinmueller, 2018; Veugelers, 2012). Indeed, the topic of policy mixes has received increasing interest in innovation studies over the last five years, with several contributions published in *Research Policy* (e.g. Flanagan et al., 2011; Kivimaa and Kern, 2016; Rogge and Reichardt, 2016) and other innovation studies journals (e.g. Borrás and Edquist, 2013). Initially innovation scholars mainly focussed on policy mixes defined as "[t]he combination of policy instruments, which interact to influence the quantity and quality of R&D investments in public and private sectors" (Nauwelaers et al., 2009, p. 3), where the research questions are often about the ideal combination of instruments to achieve a specified policy goal.

This academic interest is mirrored by an increasing recognition of policy makers that it is useful to view innovation policy through the lens of policy mixes. One example is a study commissioned by the European Commission to investigate which mixes of policies are most effective to increase the quantity and performance of research investments (Nauwelaers et al., 2009). Another example is the OECD Science, Technology and Innovation Outlook 2016 which has a chapter on 'Policy mix for business R&D and innovation' (OECD, 2016). The report understands policy mixes as being comprised of policy rationales, arrangements and instruments implemented in a specific policy domain, and sees interactions between instruments as central. A third example is the report of the International Energy Agency (2017) on 'Real-world policy packages for sustainable energy transitions' which acknowledges that a variety of different instruments need to be combined into coherent policy packages, while pointing out that there is no one "right" policy package as national objectives and constraints differ. This interest represents a real advance

* Corresponding author.
E-mail addresses: florian.kern@ioew.de (F. Kern), k.rogge@sussex.ac.uk (K.S. Rogge), howlett@sfu.ca (M. Howlett).

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over earlier policy discussions about the optimal selection of (individual) policy instruments based on criteria such as economic efficiency or cost-effectiveness (e.g. Goulder and Parry, 2008; Sterner and Coria, 2012), but also raises many new questions for further academic work in the context of sustainability transitions.

For such transitions, with the decarbonisation of the energy system and the whole economy being a prime example (Markard et al., 2012), it has been argued that policy mixes are required in order to address not only traditional market failures such as underinvestment in R&D or negative environmental externalities of greenhouse gas emissions, but also structural and transformational system failures, such as institutional failures or failures regarding the direction of a transformation process (Weber and Rohracher, 2012). The importance of policy mixes in addressing this array of failures in order to address societal challenges such as the climate crisis, have also been recognized by the OECD in its report on system innovation (OECD, 2015). Also Schot and Steinmueller (2018, p. 1563) argue that transformative change towards sustainability requires a mix of policies and that "any new policy attempt must navigate pre-existing policies and find ways to create a productive layering of existing and new policies". Policy mixes aimed at stimulating sustainability transitions are particularly challenging for a number of reasons: they normally go beyond single policy domains (e.g. they cannot be addressed by innovation policy alone but also need changes in other policy fields such as market regulations or tax rules); there is large uncertainty about future developments (e.g. technical, political, cultural); and the desired direction of change and the complexity of the change process is significant as transitions go beyond technologies (e.g. also require changes in infrastructures, social practices, and market arrangements).

In this special issue we follow calls by Flanagan et al. (2011) and Rogge and Reichardt (2016) for conceptualising policy mixes with a broader understanding going beyond ideal combinations of policy instruments. Flanagan et al. (2011, p. 702) advocate a multi-actor, multi-level analytical approach to policy mixes which also incorporates a "dynamic understanding of the processes by which policies emerge, interact and have effects". They also point to the importance of differences in institutional contexts and that there are no unambiguously 'good' mixes. To develop such an approach they draw on insights from evolutionary economics as well as the policy studies literature. Similarly, Rogge and Reichardt (2016) conceptualise policy mixes as not only being constituted of interacting instruments, but also include corresponding policy strategies with their long-term targets, policy mix characteristics (such as consistency or credibility) and policy processes which shape the policy mix in their conceptualisation. These broader conceptualisations pay more explicit attention to dynamics over time, characteristics of policy mixes, the different actors and levels of policy action involved in shaping policy mixes, as well as the policy processes themselves and the impacts of policy mixes.

Given this 'broadening' of policy mix thinking, we argue that research on policy mixes within the innovation studies field would benefit from more cross-fertilization with related work in the policy studies literature (e.g. Howlett et al., 2015; Howlett and Rayner, 2007) as already proposed by Flanagan et al. (2011). In this literature, policy mixes are typically understood as "complex arrangements of multiple goals and means which, in many cases, have developed incrementally over many years" (Kern and Howlett, 2009Kern and Howlett, 2009, p. 395). Such arrangements more often than not evolve through layering of potentially incoherent policy goals and inconsistent instruments over time. This literature focusses on assessing policy mixes against certain characteristics such as coherence and consistency as proxies for their potential success, which has already been taken up in the context of low-carbon innovation (Costantini et al., 2017; Kern et al., 2017; Kern and Howlett, 2009; Rogge and Schleich, 2018). The potential 'fit' of proposed new policy programmes or instruments with their governance context is also considered important (Howlett and Rayner, 2013). One of the key arguments in the policy studies literature is that new policy developments are constrained by previous policy choices. For example, Howlett and Rayner (2007) argue that the implementation of new policy programmes and governance arrangements depends on a number of well-understood processes such as increasing returns and other kinds of positive feedbacks, sunk costs, and incremental policy learning which are all very familiar to innovation scholars. This line of research is often not directly aimed at deriving policy recommendations about optimal policy design, but about explaining how mixes develop over time and is therefore complementary to the research on policy mixes in STI studies.

We suggest that drawing on policy studies can enrich discussions about policy mixes within the innovation studies community by offering a broader set of conceptualisations, analytical frameworks and methodological approaches for analysing policy mixes. This special issue therefore brings together contributions from scholars in innovation studies as well as policy studies in order to facilitate cross-fertilisation of ideas and the further advancements of research on policy mixes. The ambition of the special issue is to support the emergence of a new strand of interdisciplinary social science research on policy mixes that actively combines approaches, methods and insights from both fields. Specifically, the special issue has three aims:

1) To promote conceptual and methodological novelty in the way innovation scholars understand and study policy mixes by bringing together a collection of authors from innovation studies and policy studies;
2) To increase the visibility of the topic of policy mixes for sustainability transitions within the field of innovation studies by showcasing high quality conceptual and empirical studies of policy mixes;
3) To synthesize relevant policy insights derived from the emerging academic work on policy mixes for sustainability transitions, thereby responding to the recent interest in policy mixes by organisations such as the OECD, the European Commission or the International Energy Agency.

Building on the broadening of the concept of policy mixes discussed above, the special issue contributions, which empirically are focusing on policy mixes for sustainability transitions, are clustered in five key research themes which are introduced in more detail in Section 3: methodological advances in studying policy mixes; processes of policy making and implementation; a focus on actors and agency in the context of policy mixes; questions around how to evaluate policy mixes; and the co-evolution of policy mixes and socio-technical systems over time.

The remainder of this introductory article proceeds as follows: The next section presents a bibliometric analysis of the literature on policy mixes, starting with a general overview and then zooming in on contributions of the fields of innovation studies and policy studies, as well as highlighting some emerging linkages between these two strands. Section 3 introduces the key research themes of the special issue and summarises the contributions made to these themes by the papers in the special issue. Section 4 concludes by offering some critical reflections on the state of the field and deriving lessons learned for policy makers and scholars alike.

2. Bibliometric analysis: policy mixes in innovation and policy studies

Over the past two decades, research on policy mixes has experienced increasing interest, with studies on innovation and more recently also transitions being an important contributor to this trend since 2014 (see Fig. 1). In order to obtain a better overview of this expanding field we conducted a bibliometric analysis of academic articles discussing policy mixes, instrument mixes, policy portfolios and policy packages, thereby recognizing the variety of terminology used in policy mix studies. Through a topic search (TS) in the Web of Science Core Collection (WoS) we first searched for any paper utilizing these terms in its title, abstract or keywords (see Section 2.1), before zooming in into two subsets: policy mix articles published in innovation studies (see Section 2.2) and those published in policy studies (see Section 2.3). Table 1 provides an overview of

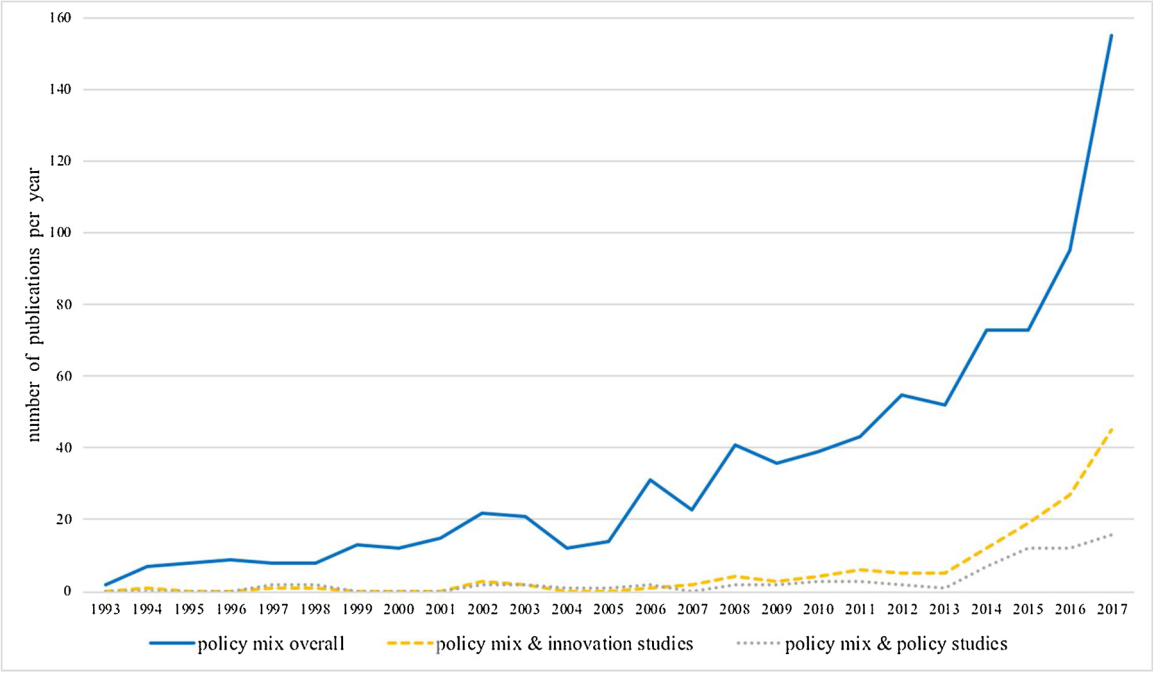

Fig. 1. Policy mix publication trend (1993–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

Table 1
Search terms for bibliometric policy mix analysis and resulting number of studies (1993–2017).
Source: Own, resulting number of studies based on data from Web of Science (as of December 21, 2018).

Academic field	Search terms	No. of papers
Any	TS = ("polic* mix*" OR "instrument mix*" OR "instruments mix*" OR "polic* portfolio*" OR "polic* package*")	894
Innovation studies	TS = ("polic* mix*" OR "instrument mix*" OR "instruments mix*" OR "polic* portfolio*" OR "polic* package*") AND TS = ("innovation*" OR "sustainab* transition*" OR "socio-technical transition*")	141
Policy studies	TS = ("polic* mix*" OR "instrument mix*" OR "instruments mix*" OR "polic* portfolio*" OR "polic* package*") AND TS = ("polic* design*" OR "polic* science*" OR "polic* stud*" OR "public administration*" OR "political science*" OR "polic* implementation" OR "polic* process*")	72

the corresponding search terms we identified through an iterative search process and the resulting overall publication figures up to 2017, with 1993 being the first year with two policy mix publications on record.[1]

For our bibliometric analysis we downloaded the full record and cited references of academic articles included in the Web of Science Core Collection on December 21, 2018 for the period between 1900 and 2017. This data was then used in the software CitNetExplorer to generate citation trees for obtaining a 'big picture' of all policy mix studies, and for policy mix publications in 'innovation studies' and 'policy studies' more specifically (van Eck and Waltman, 2014). We also analysed the publication data with the software VosViewer to conduct co-word analysis within the 'innovation' and 'policy studies' groups as well as co-authorship analysis within these two fields (van Eck and Waltman, 2013).

2.1. Overview of policy mix studies

Research investigating policy mixes has seen an increasing trend, with most articles having been published over the last 20 years, namely 833 of the total 894 publications up to 2017. As early as in 2002 research on policy mixes had already seen more than 20 academic articles per year. While initially most articles discussed economic policy, already in the nineties these started to be increasingly complemented by contributions in environmental policy. By 2008 the number of annual publications had climbed to over 40, and by 2017 it had reached a peak of over 150 (see Fig. 1), with many of the later studies related to policy mixes addressing environmental and in particularly climate policy objectives, as well as more attention on policy mixes in innovation studies (see next section).

The large majority of policy mix studies in our sample use the term 'policy mix' (502, or 56.2% of all articles), followed by 'policy package' (275, or 30.8%), whereas the terms 'policy portfolio' (86, or 9.6%) or 'instrument mix' (51, or 5.7%) are used much less frequently. These are not clear-cut boundaries, however, as several articles use multiple terms. As we are interested in illuminating the development of thinking around the notion of policy mixes in the widest sense we include all of these terms in our further analysis.

Fig. 2 shows the citation tree for ~70 of the most cited publications

[1] We also considered alternative search strategies, such as limiting the search to key journals in both fields and analysing sub-groups based on WoS categories. However, as a result of our iterative search process in which for each step we manually checked the quality of a sub-set of the resulting sample (in terms of inclusion and omission of relevant papers in the two sub-groups), leading us to adjust the search terms until we found the updated search terms to yield a good overview of policy mix studies (see Table 1). Of course, for the sub-groups the search terms are not free from limitations, as still some studies may be included which are not relevant for the field, while others may be overlooked if they do not fully meet the search criteria. For example, one highly cited paper on policy mixes published in *Policy Sciences* (Kern and Howlett, 2009) does not come up in the sub-group search for policy studies because it does not fulfil these relatively narrow search criteria, as while it contains the policy mix keyword it, however, does not use any of the policy studies related keywords. This is a general limitation of this kind of research and could only be mitigated by extensive manual checks which were beyond the scope of this work.

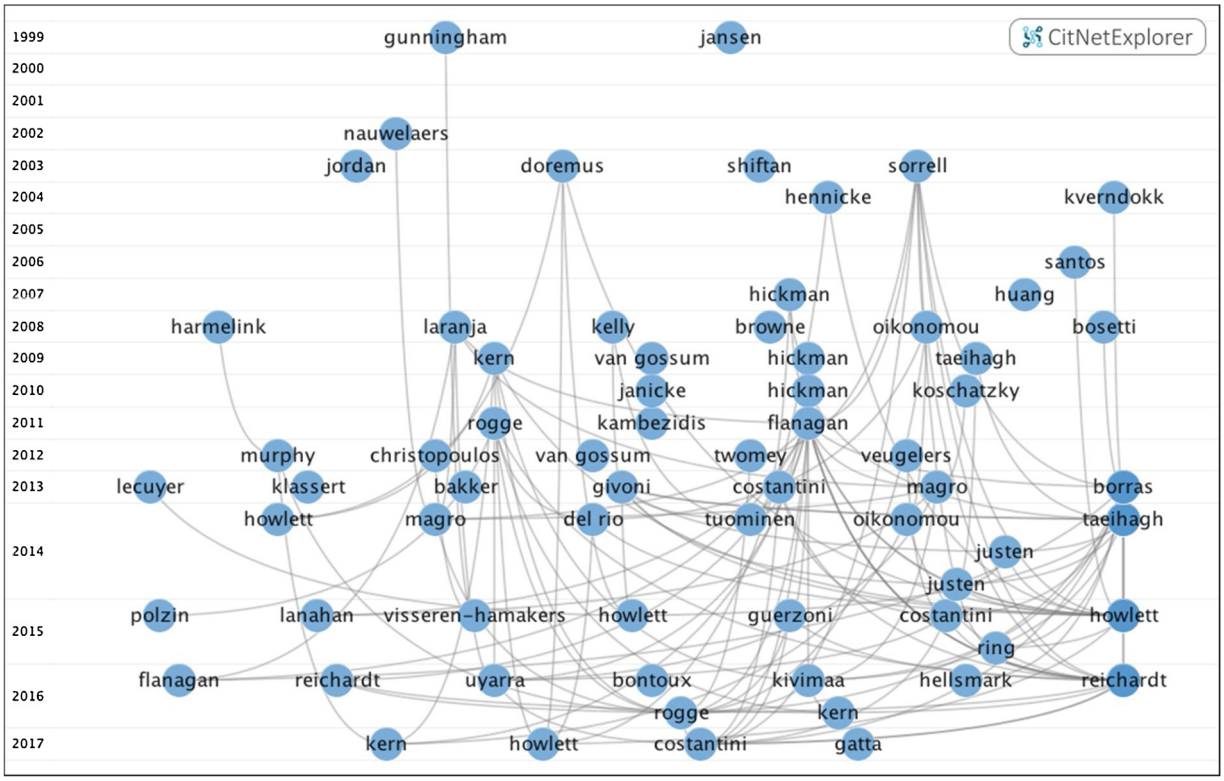

Fig. 2. 'Big picture' view of highly cited policy mix studies (1999–2017).
Source Own, based on data from Web of Science (as of December 21, 2018).

Table 2
Ranking in 'innovation' group by number of policy mix publications (#) per organisation, country, author and journal (1994–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

Rank	Organisation	#	Country	#	Author	#	Journal	#
1	University of Sussex (UK)	14	UK	37	Rogge K.	8	Energy Research and Social Science	16
2	Fraunhofer Society (DE)	10	Germany	28	Uyarra E.	6	Research Policy	12
3	University of London (UK)	7	Netherlands	16	Kern F.	5	Energy Policy	10
4	University of Manchester (UK)	7	USA	16	Carraro C.	4	Technological Forecasting and Social Change	7
5	Chalmers University of Technology (SE)	4	Italy	15	Flanagan K.	4	Environmental Politics	4
6	Maastricht University (NL)	4	Spain	10	Kivimaa P.	4	Energy Economics	3
7	Universita ca Foscari Venezia (IT)	4	Denmark	9	Costantini V.	3	Environmental Policy and Governance	3
8	University College London (UK)	4	Sweden	8	Crespi F.	3	Science and Public Policy	3
9			Canada	7	Reichardt K.	3		
10					Tavoni M.	3		

Note: The following cut off points apply regarding the minimum number of publications: institutions (at least 4), country (at least 7), author (at least 3), and journal (at least 3).

on policy mixes (see also Annex A in the supplementary material for a TOP20 overview of these).[2] The pioneering publication on policy mixes was authored by Gunningham and Sinclair (1999) on policy mixes for environmental protection which argued for going beyond single instrument approaches, albeit not blindly as different instrument combinations can be productive, counterproductive but also context specific. Another particularly influential article was published by Sorrell and Sijm on carbon trading in the policy mix (2003) discussing interaction effects arising from the introduction of CO_2 emission trading schemes, and a study by Flanagan et al. (2011) on reconceptualizing policy mixes for innovation with a particular focus on tensions and interactions across different dimensions.

For the purposes of the special issue, we are particularly interested in two subsets of policy mix articles: those within innovation studies and those within policy studies. Therefore, in the following we zoom into these two subsets to obtain more detailed insights into how these two fields have developed.

2.2. Policy mixes in innovation studies

We zoomed in on the 'innovation' group of articles to better understand the policy mix literature focussed on innovation, socio-technical transitions and sustainability transitions. As shown in Fig. 1 and Table 1 until 2017 the 'innovation' group has produced 141 academic

[2] The citation tree for the 200 connected components of the total 894 publications displays ~70 publications which were selected by CitNetExplorer based on citation scores (van Eck and Waltman, 2017). This results in an underrepresentation of more recent publications. For example, in 2017, 155 articles on the theme were published compared to 52 articles in 2013. However, Fig. 2 gives the impression that there were significantly more publications in 2013 than in 2017. In addition, the method disguises that the newer publications are dominating the highly cited papers in the policy mix field. For example, 10 of the 17 highly cited papers were only published in 2017 and 2016.

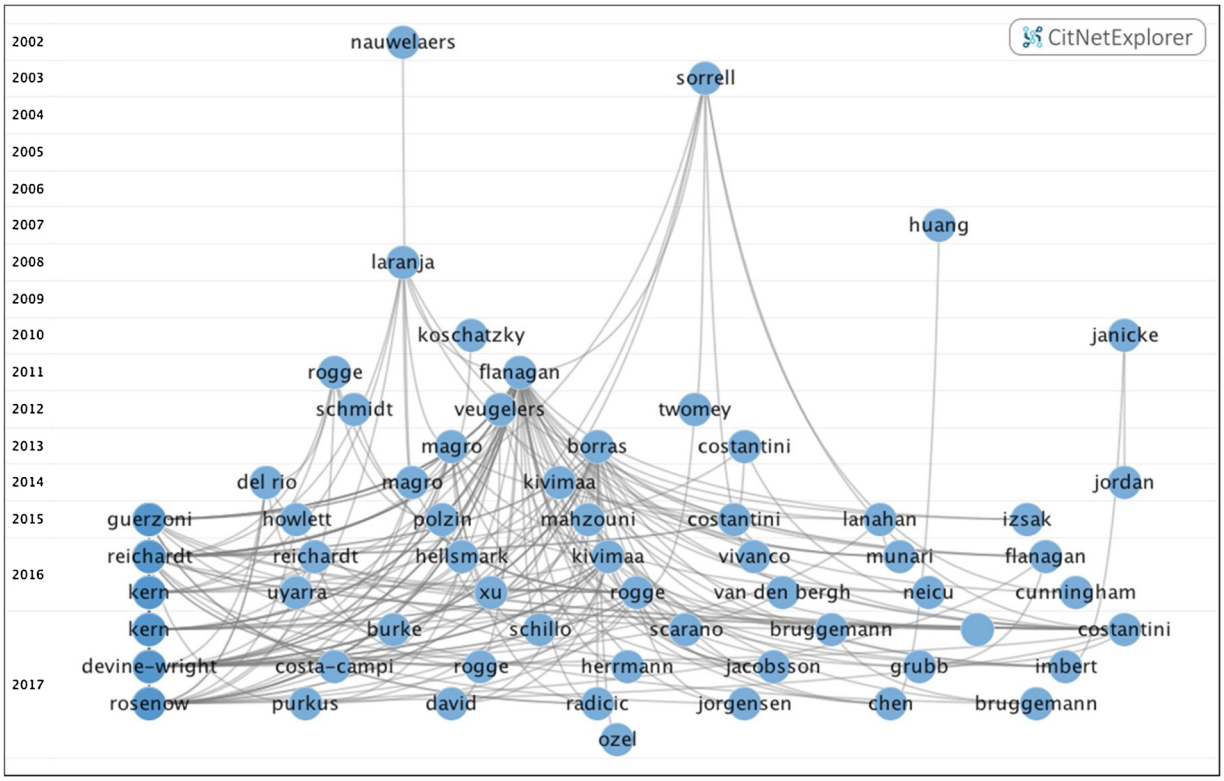

Fig. 3. Citation tree of the 'innovation' group within the policy mix field (2002–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

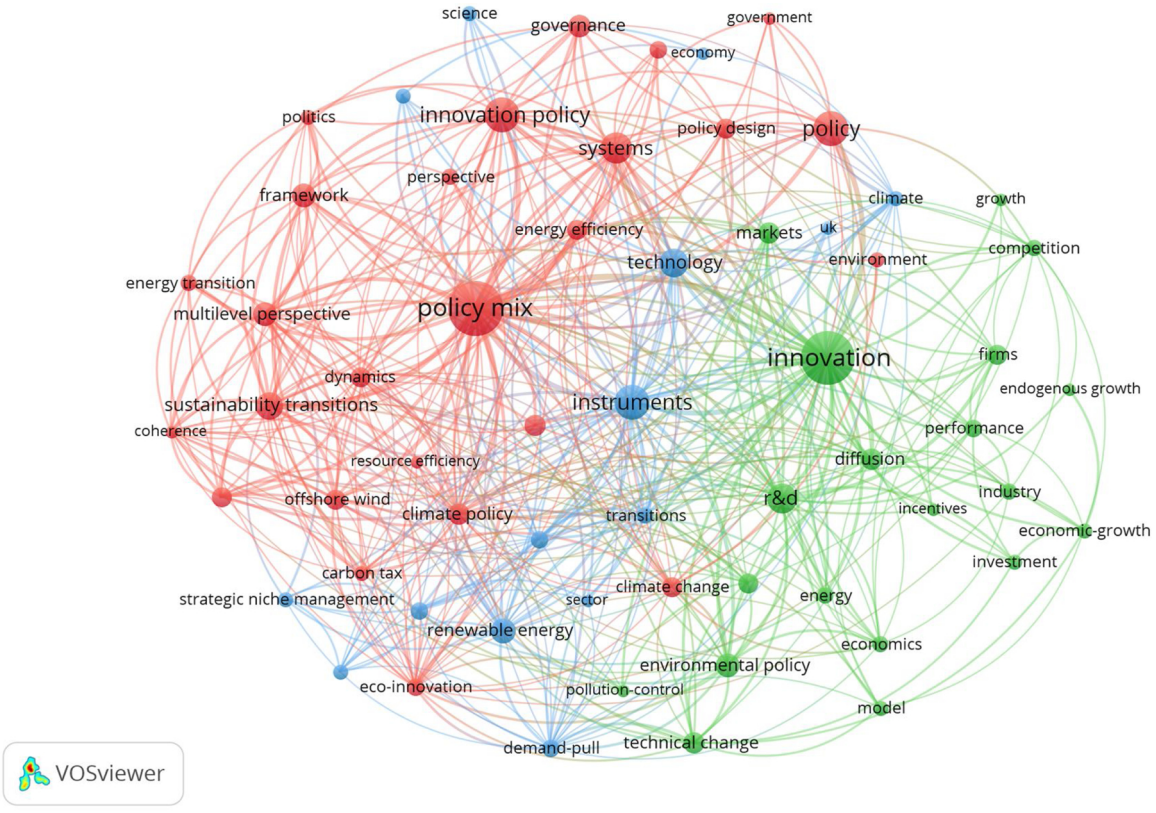

Fig. 4. Co-word cluster analysis of 'innovation' group using author key words (1994–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

Table 3
Ranking in 'policy studies' group by number of policy mix publications (#) per organisation, country, author and journal (1997–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

Rank	Organisation	#	Country	#	Author	#	Journal	#
1	National University of Singapore (SG)	5	UK	15	Howlett M.	5	Energy Policy	6
2	Simon Fraser University (CA)	5	USA	14	Del Rio P.	3	Energy Research and Social Science	5
3	Fraunhofer Society (DE)	4	Germany	12	Borner J.	2	Policy Sciences	4
4	Helmholtz Association (DE)	4	Canada	11	Carraro C.	2	Journal of Cleaner Production	3
5	CSIS - Spanish National Research Council (ES)	3	Netherlands	10	Flanagan K.	2	Energy Economics	2
6	Tsinghua University (CN)	3	Spain	8	Gawel E.	2	Research Policy	2
7	University of Oxford (UK)	3	Australia	6	Rayner J.	2		
8	University of Sussex (UK)	3	Singapore	6	Rogge K.	2		
9			Italy	3	Segafredo L	2		
10			China	3	Taeihagh A.	2		
11			Sweden	3	Uyarra E.	2		
12					Wunder S.	2		

Note: The following cut off points apply regarding the minimum number of publications: organisation (at least 3 publications), country (at least 3), author (at least 2), and journal (at least 2).

articles (the first in 1994), with a large majority of them on innovation rather than transitions, and with a particular strong growth over the last four years.

While the number of studies is limited, a closer look at the top organisations, countries and authors active in the field, and the journals having published studies on policy mixes for innovation and transitions (see Table 2) reveals some interesting insights. Among others, our analysis shows that publications on policy mixes within the 'innovation' group have largely originated in Europe (and here particularly in the UK and Germany), but that the US and Canada have also made significant contributions to the field. In addition, there are three top publication outlets in the 'innovation' group, which together account for 38 of the 141 journal articles (i.e. 27%): *Energy Research and Social Science*, *Research Policy* and *Energy Policy*.

When taking a closer look at the links between the identified 141 publications in the 'innovation' group we find that 79 publications are connected by direct citation. Fig. 3 shows the resulting citation tree which highlights the early influence of two EU funded research projects for the development of the field: one project in the field of innovation policy (linked with Nauwelaers and Wintjes, 2002) and one in the field of climate policy (linked with Sorrell and Sijm, 2003). The citation tree also shows that the divide between innovation and climate policy has started to be overcome from 2014/2015 onwards, with increasing connections between the two. The visualisation also shows the vastly growing number of well-connected outputs from 2016 onwards. For a list of the most cited papers in this group, which is led by the seminal article by Flanagan et al. (2011), see Annex B in the supplementary material.

Based on the key words provided by authors of the 141 publications within the 'innovation' group we also conducted a co-word analysis with VosViewer. Fig. 4 displays three main clusters based on how frequently key words are used in the same publication. The green cluster (on the right) focuses on innovation economics, while the red one (on the left) is mainly concerned with innovation policy and sustainability transitions. In contrast, the blue cluster (in the middle) centers around policy instruments and technology, in particular in relation to renewable energy.

2.3. Policy mixes in policy studies

We now zoom in on policy mix research focussing on policy design, policy implementation and policy processes – regardless of attention paid or not paid to innovation or transitions – to better understand the policy mix literature within the fields of policy studies, public administration and political science. As shown by the dotted grey line in Fig. 1 and the numbers in Table 1 the 'policy studies' group is the smaller subset of the two groups of interest here. By the end of 2017 it had produced 72 academic articles, with the first two published in 1997. A significant share of these studies also belong to the 'innovation' group (23 publications), demonstrating that innovation scholars have engaged with policy making and implementation processes. Finally, the rate of growth in the 'policy studies' group has been smaller than in the 'innovation' group and the even faster growing overall policy mix literature.

A closer look at the top organisations, countries, authors and journals in the 'policy studies' group reveals – despite the small numbers – some interesting differences to the 'innovation' group (see Table 3). For example, a more international picture emerges, with most contributions from the UK, USA, Germany, Canada and the Netherlands. Also, the field is rather dispersed with publications spread out amongst 56 different journals, with 50 of these only having published one policy mix article. Also, it is noteworthy that there is only one dedicated policy studies journal in the top journal group, namely *Policy Sciences* (with 4 articles).

The dispersed nature of the 'policy studies' group is also illustrated by Fig. 5 showing those publications that are connected by direct citation, which is the case for only 23 out of the 72 articles. We find that two publications are of central relevance in the citation tree: Doremus (2003) on the design, implementation, evaluation and revision of biodiversity policy portfolios and Flanagan et al. (2011) with their attention to policy making and policy coordination in the context of policy mixes for innovation. Indeed, Kieron Flanagan and his co-authors Elvira Uyarra and Manuel Laranja with their explicit emphasis on policy processes in the context of policy mixes is the most cited paper in this group (see Annex C in the supplementary material), just as was already the case in the 'innovation' group. Overall, however, the 'policy studies' group is not only smaller, but also much less connected than the 'innovation' group, suggesting that there may only be a weak community of practice involved in policy mix studies within the 'policy studies' group. Yet, in the past few years the connections between policy mix publications in this group have increased. Part of this development is driven by articles on innovation, as highlighted by the overlap in the 23 publications appearing in both groups.

Our analysis of key words further illustrates the dispersed nature of the 'policy studies' group. Again, we performed a co-word analysis with VosViewer, using the key words provided by the authors of the 72 publications in this group. Fig. 6 displays colour-coded clusters based on how frequently key words are used in the same publication. Again, three different clusters emerge, with a central position of policy design and instruments. While the green cluster (top left) mainly captures studies addressing the topic of policy instruments and innovation in the fields of climate, environmental and renewable energy policy, the blue cluster (bottom left) unites studies on governance, coordination, implementation and politics more generally. However, the largest cluster

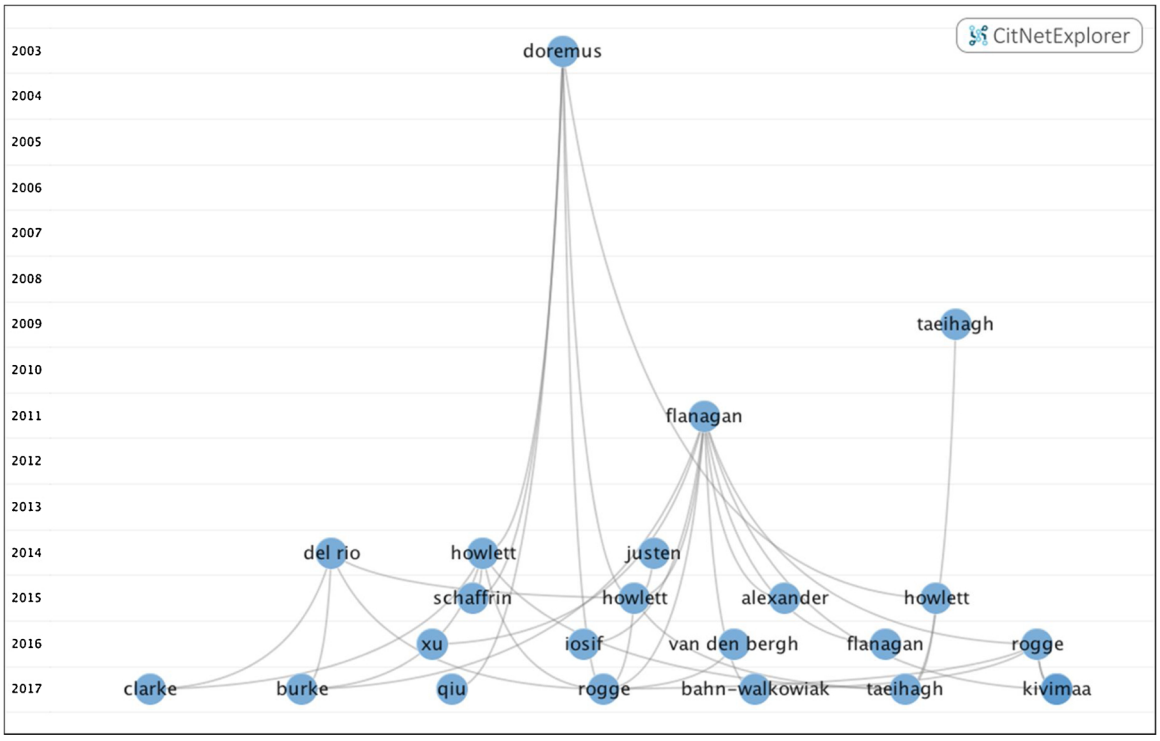

Fig. 5. Citation tree of the 'policy studies' group within the policy mix field (2003–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

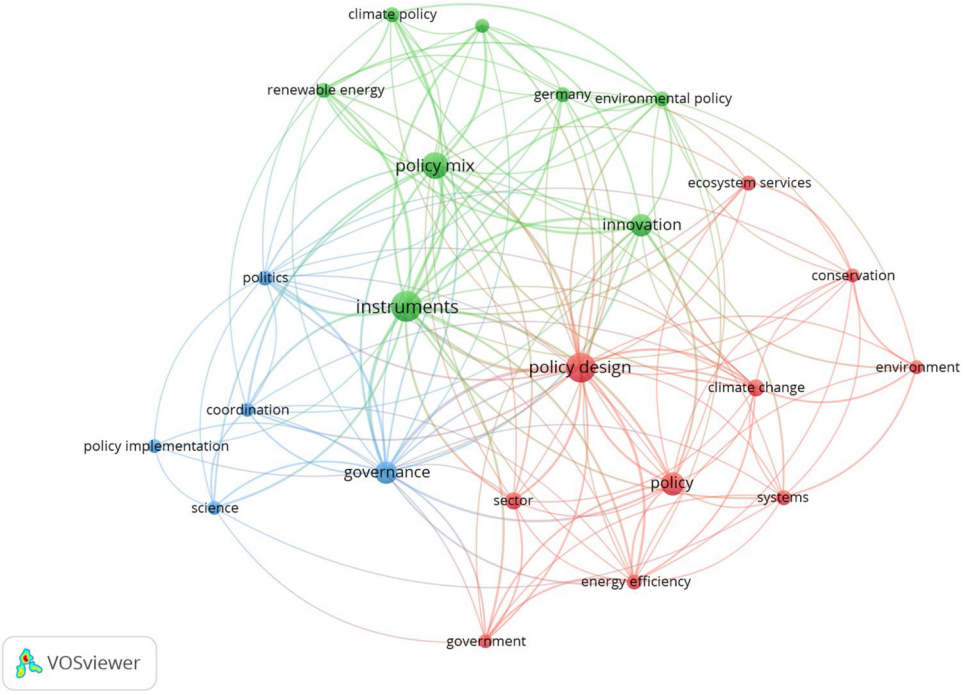

Fig. 6. Co-word cluster analysis of 'policy studies' group using author key words (1997–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

is the red one (on the right) which revolves around discussing policy design in a policy mix setting, with empirical studies largely focusing on environmental and climate policy, conservation, ecosystem services and energy efficiency, typically approached from a systems perspective.

2.4. Emerging links between innovation and policy studies groups

One of the key aims of this special issue is the bridging of conceptual, methodological and empirical developments across innovation and policy studies in order to be better able to investigate policy mixes for sustainability transitions. To get a sense of the starting point for such an endeavour we merged the 141 policy mix publications from the

Table 4
Ranking for combined 'innovation' and 'policy studies' groups by number of publications per organisation, country, author and journal (1994–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

Rank	Organisation	#	Country	#	Author	#	Journal	#
1	University of Sussex (UK)	14	UK	46	Rogge K.	8	Energy Research and Social Science	16
2	Fraunhofer Society (DE)	11	Germany	35	Uyarra E.	6	Energy Policy	13
3	University of London (UK)	8	USA	27	Howlett M.	5	Research Policy	12
4	University of Manchester (UK)	7	Netherlands	22	Kern F.	5	Technological Forecasting and Social Change	7
5	Helmholtz Association (DE)	6	Italy	16	Carraro C.	4	Environmental Policy and Governance	4
6	Simon Fraser University (CA)	6	Spain	16	Flanagan K.	4	Environmental Politics	4
7	Chalmers University of Technology (SE)	5	Canada	15	Kivimaa P.	4	Journal of Cleaner Production	4
8	National University of Singapore (SG)	5	Denmark	10			Policy Sciences	4
9	University of Oxford (UK)	5	Sweden	10			Science and Public Policy	4

Note: The following cut off points apply regarding the minimum number of publications: organisation (at least 5 publications), country (at least 10), author (at least 4), and journal (at least 4).

'innovation' group with the 72 publications from the 'policy studies' group. This yields 190 publications in the combined 'innovation and policy studies' group (due to the overlap of 23 articles).

For these publications, Table 4 shows that the UK is clearly dominating the ranking, with four universities among the leading organisations and a total of 46 publications (or 24.2% of all publications in the combined 'innovation and policy studies' group). It is followed by Germany, with two research associations among the leading organisations and a total of 35 publications (or 18.4%). Most research has been published in the journals *Energy Research & Social Science* (16 articles), *Energy Policy* (13) and *Research Policy* (12).

We now turn to an analysis of already existing collaborations between authors within the combined 'innovation and policy studies' group. For this, we used VosViewer to visualize the frequency of co-authorship. From the 190 publications in the 'innovation and policy studies' group a total of 464 authors were identified (411 of them with at least one citation), of which, however, only 38 were found to have collaborated with another author in the combined group. The co-authorship between these connected authors is shown in Fig. 7. The visualisation shows five clusters of closely related publications (van Eck and Waltman, 2013, p. 5). The size of each node represents the number of documents the author is associated with and the thickness of the line connecting authors represents the frequency of collaboration. Overall, the co-authorship analysis shows that collaboration between policy studies and innovation studies scholars has remained limited, with only one of the clusters (the dark blue one on the bottom left formed around Mike Howlett) representing original policy studies. In contrast, the majority of clusters and authors are rather associated with the field of innovation studies as well as focusing on energy and climate policy, but who are engaging with policy studies. Thus, while some authors have started to build the bridges we want to strengthen with this special issue, there is still much potential for more and deeper connections.

3. Overview of the contributions to the special issue

In this section, we provide an overview of the nine contributions included in this special issue (see summary in Table 5). As can be seen, six of these papers build on the extended policy mix concept developed by Rogge and Reichardt (2016), while the other three utilize the policy mix definition offered by Kern and Howlett (2009). Empirically, the majority of contributions focuses on energy transitions, covering different aspects such as renewable electricity, housing, or energy storage, but there are also contributions on health policy or regional smart specialisation. The geographic scope of the papers is largely limited to

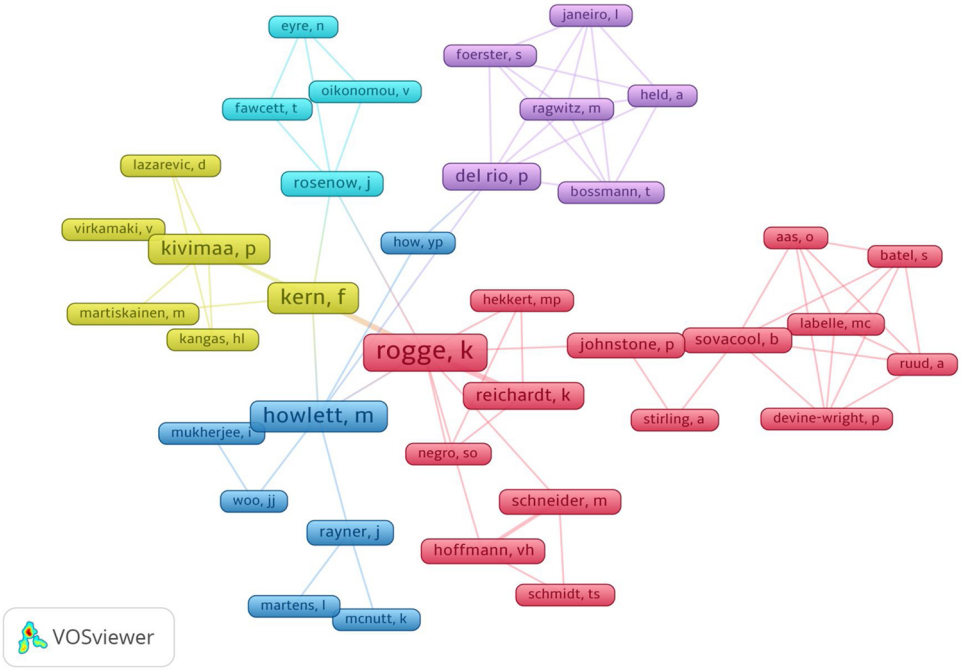

Fig. 7. Collaboration between policy mix authors in innovation and policy studies (1994–2017).
Source: Own, based on data from Web of Science (as of December 21, 2018).

Table 5
Overview of contributions to the special issue.

Title	Author(s)	Policy mix definition	Method	Empirical case	Main policy implications	Future research implications
Delineating policy mixes: Contrasting top-down and bottom-up approaches to the case of energy-storage policy in California	Ossenbrink, Finnsson, Bening, Hoffmann	Rogge and Reichardt, 2016	document analysis, expert interviews	Energy storage, California	Distinction between top-down and bottom-up approaches to map policy mixes: depending on applied approach resulting policy mix can vary significantly.	Dynamic policy mix mapping for several time steps; quantitative analysis of effects of policy mixes; estimate and contrast individual and combined impact of policy instruments; conceptual refinements.
Measuring the temporal dynamics of policy mixes – An empirical analysis of renewable energy policy mixes' balance and design features in nine countries	Schmidt and Sewerin	Kern and Howlett, 2009	Index of Policy Activity (IPA) and panel regression with OLS estimation	Renewable energy policies in nine countries (AU, AT, CA, DE, IE, NZ, ES, CH, UK)	Reassess the potential of 'layering' to serve as a realistic design strategy for more effective policy mixes.	Greater focus on policy mix design, including general and policy-field related issues; more detailed analysis of the determinants of similarities and differences in policy mixes' balance, intensity and technology specificity; dynamics during periods of policy 'dismantling'.
Lost in translation: How legacy limits the OECD in promoting new policy mixes for sustainability transitions	Diercks	Kern and Howlett, 2009	Desk research, semi-structured interviews, participant observation	OECD	Strategies against sticking points: address them directly or debunk the underlying myth; Circumvent the challenge of changing OECD as an actor by shifting venues of decision making or looking to actors with fewer stakes in the old paradigm.	Institutionalisation of new policy paradigms; development of system innovation indicators or metrics
Mapping the mix: Linking instruments, settings and target groups in the study of policy mixes	C. Mavrot, S. Hadorn, F. Sager	Kern and Howlett, 2009	Mixed method approach, combining document content analysis, interviews, time series analysis of self-evaluation questionnaires	Tobacco control policies, Switzerland	Consider settings for policy design as this can lead to higher policy performance; harness network management for mobilization and implementation of policies.	Learn from health policy research; focus on micro- and meso-factors and their influence on overall policy.
Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix	Lindberg, Markard, Andersen	Rogge and Reichardt, 2016	Coding of policy mixes and actor preferences, based on documentary analysis, interviews, expert consultation	EU energy policy	EU energy policy mix needs to be constantly aligned with technological developments around solar power, smart grid technology and distributed storage which are continuously making a decentralized-RES pathway more feasible and where decentralized technologies are competitive, reliable, and rapidly expanding.	Apply methodology over time
The acceptance of instruments in instrument mix situations: Citizens' perspective on Swiss energy transition	Ingold, Stadelmann-Steffen, Kammermann	Rogge and Reichardt, 2016, focusing on instrument mix	Logistic multi-response regression models, with Bayesian estimation approach	Energy and climate policy, Switzerland	Information provision for shaping citizens' preferences is important. Policy makers must enable citizens, but also sensitize about the 'bigger picture' to increase the legitimacy of energy transitions.	Improve measurement of individual perceptions of and experience with instrument mixes; disentangle the relative contribution of citizens to policy change, compared to firms, scientific institutions, or the political elite.
Policy-mix evaluation: Governance challenges from new place-based innovation policies	Magro and Wilson	Rogge and Reichhardt (2016), focusing on three additional elements: verticality, directionality, and capacity to facilitate experimentation	Literature review, documentart analysis, interviews, work with stakeholders	Regional smart specialization strategies, illustration through Basque region, Spain	New governance arrangements for policy mix evaluation: ensure strong links between government departments and levels involved; novel evaluation methods in which empowerment principles are present.	Linking of governance structures and processes for evaluation as key issue in the context of place-based policy mixes: evaluate practices of smart specialization strategies in different regions.
The co-evolution of policy mixes and socio-technical systems: Towards a conceptual framework of policy mix feedback in sustainability transitions	Edmondson, Kern, Rogge	Rogge and Reichardt, 2016	Literature review, document analysis	Low carbon building sector, UK	Policy mix should not only create incentives for emerging niche actors but also for powerful actors to support the transition. Timing and sequencing of policies should be relative to the phase of the transition.	Extend the scope of fiscal feedback mechanisms; link policy mix characteristics to policy feedbacks; incorporate vertical dimensions of policy mixes
	Huang	Rogge and Reichardt, 2016	Expert interviews and event history analysis	Solar Water Heating in Shandong, China	Consider dynamic vertical interactions between different governance levels.	

(*continued on next page*)

Table 5 (*continued*)

Title	Author(s)	Policy mix definition	Method	Empirical case	Main policy implications	Future research implications
The verticality of policy mixes for sustainability transitions: A case study in China					Policy learning process: recognize co-evolutionary and temporal nature of policy mixes.	Develop more nuanced and dynamic perspectives on the design of multi-level policy mixes.

Europe, North America and China. Methodologically, the special issue includes not only qualitative but also quantitative as well as mixed methods contributions, with many offering novel approaches for the emerging literature on policy mixes in STI studies.

Building on the bibliometric analysis in Section 2 as well as our reading of the relevant literature, we identified five important themes within policy mix research for sustainability transitions which would particularly benefit from bridging innovation and policy studies. These themes are introduced in the subsections below, followed by a summary of the contributions that the papers in this special issue make to them.

3.1. Methodological advances in policy mix research

Analysing policy mixes is a challenging endeavour. While it may seem relatively easy to develop conceptual frameworks and typologies of policy mixes, it may be more challenging to develop and systematically apply appropriate methodologies for analysing them. One important challenge concerns the definition of the boundary of a policy mix. Studies of individual policy instruments find it straightforward to define the object of analysis, but for policy mixes this endeavour is much more complex. The definition of the policy mix itself of course provides some initial boundaries. For example, some policy mix concepts only include policy instruments (Borrás and Edquist, 2013; Veugelers, 2012), others include policy goals and policy instruments (Kern and Howlett, 2009) while Rogge and Reichardt (2016) argue for an extended concept of policy mixes, which includes policy elements (policy strategies and instrument mixes), characteristics of policy mixes (such as consistency, coherence, credibility and comprehensiveness) as well as policy making and implementation processes (as "political problem-solving processes among constrained social actors in the search for solutions to societal problems", p. 1625). However, even in the narrowest definition of the policy mix concept, which only includes interacting policy instruments, it is by no means straightforward to decide which instruments are included in the mix (and which are not), with this challenge becoming more pronounced with broader policy mix conceptualisations.

A second core methodological (and conceptual) challenge is how to characterise policy mixes given that they often have a significant number of elements. Much of the existing work has therefore focused on characterising policy mixes by categorising individual policy instruments e.g. into technology push or demand pull policies (Costantini et al., 2017), into carrots, sticks and sermons (Mavrot et al., this issue) or into contributing to the creation of new or the destruction of old regimes (Kivimaa and Kern, 2016). Mapping and counting the number of instruments in each category is used as a proxy for assessing the balance or comprehensiveness of the mix. However, given that such categorisations are necessarily quite crude and much research shows that the specific design of individual instruments is important for their effectiveness (e.g. Kemp and Pontoglio, 2011) as well as how they interact with other instruments in the mix (del Río and Cerdá, 2017), this is a rather unsatisfactory approach.

The challenge of delineating policy mixes is addressed by **Jan Ossenbrink, Sveinbjoern Finnsson, Catharina R. Bening, and Volker H. Hoffmann** who argue that in order to build a consistent research programme on policy mixes, it is important that there are shared heuristics for delineating policy mixes. Their literature review shows that there are two ways in which relevant elements of a policy mix can be identified, top-down or bottom-up, but that many studies do not consciously chose between the two options and provide little detail on how the policy mix is identified. The top-down approach builds on the idea that the elements of a policy mix originate from an overarching strategic policy intent, which is thus taken as the starting point and then all relevant instruments used to implement the strategy are identified. By contrast, the bottom-up approach starts from the definition of a focal impact domain that is of core interest for the respective research question (e.g. a specific technology or sector) and then searches all

policy instruments (and corresponding policy strategies) which affect decision making by actors in this domain. Importantly, Ossenbrink et al. develop a systematic analytical procedure of how to go about either of the two approaches and demonstrate how these methodological procedures can be applied in practice by conducting an analysis of the policy mix in the energy storage domain as part of California's energy transition. Their results show that there is very little overlap between the policy mixes identified through the two approaches. This supports their argument that transparency and consistency is needed in order to increase the potential for replicating studies. Overall, this paper establishes a new standard for delineating policy mixes transparently and systematically, which will hopefully provide useful guidance for future studies.

The methodological challenge of how to characterise a policy mix in more sophisticated ways is addressed by **Tobias Schmidt and Sebastian Sewerin** who conduct an analysis of renewable energy policy mixes in nine countries. The authors develop a conceptualization and measurement of policy mix balance across instrument types as well as two policy mix design features (intensity and technology specificity). While assessing the balance across instrument types is a common approach to characterise policy mixes (Costantini et al., 2017; OECD, 2016), Schmidt and Sewerin propose a novel measurement in terms of dispersion of instruments through the Gini-Simpson Index. Also, by assessing the policy mix design features the paper provides a richer analysis than simply counting the number of instruments. This is accomplished by first assessing the intensity of each individual instrument through a systematic qualitative coding procedure for which they build on Schaffrin et al. (2015), and then aggregating these into an overall intensity of the mix. In addition, the authors provide an analysis of the temporal dynamics of policy mixes which is a prominent theme in the policy sciences literature on policy mixes (e.g. Howlett and Rayner, 2007). In contrast, many studies in the innovation studies field often provide analyses of policy mixes at one point in time, which especially in the context of long-term sustainability transitions is an important weakness. The temporal analysis is used to answer the question how temporal dynamics of policy mixes differ between countries regarding their balance and design features. In sum, this paper enriches ongoing discussions about how to measure characteristics of policy mixes (Costantini et al., 2017; Rogge and Dütschke, 2018; Rogge and Schleich, 2018) and hopefully will inspire others to further advance the systematic measurement of policy mix characteristics.

3.2. Processes of policy mix formulation and implementation

One of the features of much policy mix research is the focus on the content of the policy mix, while much less attention is paid to the policy making and especially implementation processes. This is problematic if one is interested in the outcomes of policy since the policy studies literature suggests that the impacts of policies do not only depend on their design, but also on how they are being implemented (see e.g. McLaughlin, 1987 for a summary of different generations of implementation studies). Similarly, Borrás and Edquist (2013) pointed to the importance of policy implementation in contributing to differences in policy outcomes. In addition, Flanagan et al. (2011) argued that institutional contexts within which instruments operate are crucial in determining their effects. Moreover, the policy making style and the coherence of policy processes were identified as influencing factors for low-carbon innovation (Reichardt et al., 2017, 2016). Therefore, Rogge and Reichardt (2016) argued that it is important to also consider policy making as well as policy implementation processes in the context of analysing policy mixes for sustainability transitions, for which scholars can draw on various theories of the policy process (Kern and Rogge, 2018). Two of the contributions in this special issue engage with these challenges.

The paper by **Gijs Dierks** provides a rich case study of the Organisation for Economic Cooperation and Development (OECD), and examines how the OECD is shaping policy mixes for sustainability transitions. The role of the OECD is particularly interesting as it has in the past significantly shaped innovation policy in its member states, because it has recently adopted the concept of system innovation (i.e. transitions, see OECD, 2015) and has started thinking about innovation policy in terms of policy mixes (e.g. OECD, 2016). Dierks argues that system innovation thinking potentially has radical implications for innovation policy mixes and analyses how such thinking was taken up within the science, technology and innovation directorate of the OECD. He also provides an account of why this way of thinking has not been institutionalised within the OECD's core activities. The analysis shows how legacy effects – in the form of institutional, cognitive and political 'sticking points' – prevented such a translation and inscription into proposals for policy mixes for sustainability transitions. Despite initial momentum, Dierks finds that several purposeful efforts to inscribe the concept into the organisation's core activities have largely failed. The paper presents a powerful reminder of how difficult it is to overcome path dependencies and develop novel ideas about suitable policy mixes, even in organisations which have acknowledged the importance of the challenge and also cognitively have started to think in terms of policy mixes.

Building on the idea that implementation processes are key for policy outcomes, **Céline Mavrot, Susanne Hadorn and Fritz Sager** make a case for looking at the implementation context of policy mixes. In their conceptualisation this context includes the specific setting within which a policy instrument is implemented as well as the specific target group of each instrument. They argue that focussing on the specific settings where interventions are implemented allows for a more precise understanding of policy making and policy implementation. Including target groups into the analysis of policy mixes is argued to be crucial since the recipient side of policy may be as important as the sender side of policy. Building on Rogge and Reichardt (2016), the aim of the paper is to propose a conceptual framework for analysing the effectiveness of policy mixes and specifically their ability to induce behavioural change. Empirically, Mavrot et al. analyse an unusual case from an STI perspective: the implementation of tobacco control policies in Switzerland. They convincingly argue it to be an exemplary case for analysing transitions which involve significant behavioural change driven by public policy, as well as an emblematic case of an attempted managed decline of a specific product and its associated industry. The analysis triangulates different sets of quantitative and qualitative indicators in order to assess the implementation of eleven subnational policy mixes. Mavrot et al. find that taking into account implementation contexts of policy mixes improves our understanding of policy compliance at the individual level, which is crucial in policy-driven transition processes. The paper demonstrates how insights generated by the policy implementation and evaluation literature as well as health policy insights can be used to fine-tune our conceptualisation of policy mixes for sustainability transitions by paying more attention to the recipient side of policy mixes.

3.3. Actors & agency

One of the criticisms of policy mix research is that analysis often remains on a fairly abstract level, for example regarding policy layering or the co-evolution of technology and policy. However, to really understand the nature and dynamics of such processes it is important to look at the agency of actors driving them. Within the literature on sustainability transitions there is some research focussing on actors and their agency in transition processes (Farla et al., 2012; Fischer and Newig, 2016; Wittmayer et al., 2017). Recently, Duygan et al. (2019) developed a heuristic to analyse the determinants of agency in transition processes. There are also studies focussing on the role of specific actor types such as incumbents (Smink et al., 2013), intermediaries (Kivimaa, 2014), community-based initiatives (Seyfang and Haxeltine, 2012) or users (Schot et al., 2016) in transitions. Especially the

literature on the politics of transitions (Avelino et al., 2016; Köhler et al., 2019) or the policy studies literature (Howlett et al., 2009; Sabatier and Weible, 2014) provide many useful starting points for thinking more specifically about different kinds of actors and their involvement in policy processes which can be utilised in the analysis of policy mixes for sustainability transitions (Kern and Rogge, 2018). Two of the papers in this special issue focus specifically on the actors involved in developing policy mixes.

The paper by **Marie Byskov Lindberg, Jochen Markard and Allan Dahl Andersen** focusses on the EU's energy policy mix, for which it provides an assessment of key industry actors' policy preferences. This is important since transition pathways unfold as a result of continuous struggles of actors over policy goals and instruments. Given the interest in how actors and policies influence the direction of transitions, the paper asks about preferences for transition pathways, which are differentiated by two dimensions: the degree of sustainability and the degree of disruption. Lindberg et al. use this typology to map policies as well as key industry actor preferences through establishing a set of criteria and coding system for both dimensions. They show that there generally is a large overlap between current policies and actor preferences in the direction of a centralised renewable energy system, but also find many actors with strong preferences in favour of a more decentralised and more ambitious renewables pathway, which is also supported by some policies. One of the contributions of the paper is to demonstrate how actors and policy preferences can be explicitly included in the study of policy mixes.

The contribution by **Karin Ingold, Isabelle Stadelmann-Steffen and Lorenz Kammermann** focuses on citizens, which they argue to be an understudied target group of energy transition policies. Their research question is: "What are citizens' preferences towards new instruments promoting renewables in an instrument mix situation, and what factors influence these instrument mix preferences?". Conceptually, Ingold et al. draw on the social acceptance literature as well as on sustainability transitions research. Their framework differentiates between three different potential drivers for citizens' instrument preferences. The current instrument mix is assessed by looking for all policy instruments supporting three main renewable energy technologies, classifying them into four categories (tax incentives, subsidies, ban and information), and characterising the mix in terms of its density (number of instruments) and intensity (e.g. the amount of resources used, strictness of standards, etc.). Empirically, the authors draw on a survey among Swiss residents. The results show that it is mainly individual factors that contribute to the acceptance of additional policy instruments compared to context-related factors, and that respondents acknowledge that a mix of instruments will be required to meet the goals. Importantly, the analysis shows that there is no systematic relationship between the existing cantonal instrument mix and individual's instrument mix preferences. The hypothesis that instruments introduced in the past affect current instrument preferences was therefore not supported, though the authors argue that this might be a consequence of the way the policy mix was operationalised in the survey. Regardless, the methodology developed in this paper could potentially be applied to analysing policy maker or industry actor preferences', as the literature on policy path dependence and policy feedbacks suggests that such associations are plausible.

Both contributions under this theme develop interesting insights and develop analytical approaches of how to analyse actor preferences. Future studies could build on these approaches and complement them with a more processual analysis looking at the politics of the underlying policy processes through which the policy mixes develop over time to show how preferences of actor (groups) are shaping the content of policies.

3.4. Evaluating policy mixes

Policy evaluation is complex and challenging for a number of reasons, even when focusing on single instruments rather than policy mixes (Vedung, 2017). One main challenge is the problem of attribution, i.e. how one can link a specific policy intervention with a particular outcome that is claimed to have followed from the existence of the policy. In the domain of science, technology and innovation policy, theory-based evaluation has been proposed to draw on theories of the systemic nature of innovation to assess innovation policy (Arnold, 2004; Molas-Gallart and Davies, 2006). However, so far only a handful of European countries comprehensively consider policy mix questions in their evaluation of system-oriented innovation policy (Borrás and Laatsit, 2019). In the context of mission-oriented innovation policy and transformative policy mixes for socio-technical system change the challenge of policy (mix) evaluation becomes even more pronounced (Arnold et al., 2018; Fisher et al., 2018; Kivimaa et al., 2017). On the one hand, sustainability transitions are complex, uncertain and co-evolving processes calling for tailored evaluation approaches (Luederitz et al., 2017; Nieminen and Hyytinen, 2015); on the other hand policy mixes can be characterised by very different rationales, thereby complicating the question about suitable evaluation criteria, and by policies originating from different governance levels which continually interact with one another in complex ways (Magro and Wilson, 2013). As a consequence, paying attention to policy mixes for sustainability transitions challenges traditional policy evaluation approaches and has implications for the governance of evaluation practices (Boni et al., 2019), as one paper in this special issue shows.

The contribution by **Edurne Magro and James Wilson** analyses the interaction between governance processes and policy mix evaluation in the context of regional smart specialisation strategies. The challenge of evaluating such policy mixes is to better understand the impacts of policy mixes and how they contribute to the processes and direction of transformation. The aim of the paper is to analyse how strategic intelligence and learning gained through appropriately governed evaluation processes can be used to boost regional capacity building. The paper's assumption is that the usefulness of the evaluation process for learning very much depends on whether the governance of the evaluation process is seen as legitimate by the actors involved in setting the direction of the smart specialisation strategy. Conceptually, the paper draws on the policy evaluation, governance and smart specialisation literatures. Empirically, the paper explores these issues through a case study of the Basque Country in Spain. Magro and Wilson find that in the context of advanced manufacturing there are strong elements of verticality since there are five different administrative levels involved. In terms of the directionality of the policy mix they find the co-existence of neutral instruments with no directionality, instruments that support specific directions, and instruments which have been made directional to serve the strategy through a policy patching process. The Basque government is shown to have utilised a two-pronged governance approach based on experimentation: a 'hard governance' arrangement in terms of the regional government's oversight of the implementation and evolution of the strategy (and policy mix); and a 'soft governance' arrangement in terms of the wider engagement with business, research and civil society in an 'entrepreneurial discovery process'. Overall, this paper provides insights into the complexity of real-world policy mix evaluation challenges and what kinds of governance arrangements might be conducive to produce the policy learning required to develop successful smart specialisation policy mixes.

3.5. The co-evolution of policy mixes and socio-technical systems

The policy sciences literature on policy mixes acknowledges the path-dependent nature of policy making and is interested in the processes through which policy mixes evolve over time. Concepts like policy patching versus packaging (Howlett and Rayner, 2013) or policy layering (Howlett and Rayner, 2007; Kern and Howlett, 2009) have been used to study such policy mix dynamics. In the field of sustainability transitions, there have been several contributions which have

argued for a need to better understand these processes of policy development in the wider context of dynamics within the socio-technical systems which the policies are meant to address (for example Hoppmann et al., 2014; Reichardt et al., 2016). The argument is that in the context of transitions, the policy mix and the socio-technical system co-evolve over time and that transition scholars need to better understand these dynamics in order to provide better policy advice. This is reflected in recent calls for a greater emphasis of transitions research on policy feedbacks (Roberts et al., 2018; Schmidt and Sewerin, 2017).

The paper by **Duncan Edmondson, Florian Kern and Karoline Rogge** develops a novel conceptual framework which aims to shed light on the co-evolution of policy mixes and socio-technical systems over time. The framework builds on the sustainability transitions literature as well as the policy feedback literature within policy sciences to conceptualize the specific mechanisms through which this co-evolution occurs. The policy feedback literature is interested in the consequences of policy making on subsequent rounds of policymaking and its politics. The framework draws on this research strand and proposes three types of effects through which policy can shape developments of the socio-technical system (resource, institutional and interpretive effects) and three feedback mechanisms through which developments within the socio-technical system influence further policy developments (socio-political, administrative and fiscal feedbacks). The utility of this framework is illustrated through an empirical application to the case of the zero carbon homes policy mix in the UK. This ambitious policy mix initially led to some momentum towards lower carbon housing but because of a number of developments, the original policy ambitions were undermined, target groups lost their faith in the seriousness of the commitment and lobbied against it, so that ultimately the zero carbon homes ambitions were abandoned by the government. The case study illustrates the case of a failed transition and how despite initially strong policy commitment and some positive feedbacks occurring, it can be difficult for actors to maintain commitment to an ambitious policy mix in the face of difficult external circumstances. The paper contributes to understanding the maintenance of policy mixes as a challenging political process and proposes that policy makers seeking to support sustainability transitions need to attempt to design policy mixes capable of generating positive feedbacks, thereby strengthening political support over time.

The paper by **Ping Huang** explores the co-evolution of a vertical policy mix across several levels of policy making with industrial path creation. By focusing on the interactions across policy levels Huang addresses a gap in the empirical policy mix literature in which most analyses focus on the policy mix interactions and dynamics on one level of policy making. The aim of the paper is to better conceptualise interactions between multi-level policy mixes and their co-evolution with industry development. Conceptually, the paper draws on insights from policy mix research and the concept of anchoring from economic geography. Empirically, the analysis traces the industrial path creation of solar water heating technology in Shandong Province in China and its interactions with policy mix developments at several levels of policy making. It finds that there are both bottom-up and top-down patterns of policy mix development across levels of policy making and that interactions between the different levels evolved over time from unidirectional (top-down) to bidirectional (top-down and bottom-up) patterns in line with industry maturation. The paper serves as a reminder for how important local policy developments can be, but also that the temporal dimension is key as policy mixes need to change over time in line with the phase of the transition ('policy sequencing', see Meckling et al., 2017).

4. Conclusion

Research on policy mixes has significantly increased over the last few years, with the topic also having received increasing attention from policy makers interested in directing and accelerating socio-technical transitions towards sustainability. This article has taken stock of the literature on policy mixes in the context of innovation policy and sustainability transitions and analysed emerging collaborations between scholars from innovation and policy studies. It summarised the contributions to the special issue and positioned them within five research themes for which we see much potential to bring together insights from innovation and policy studies.

All papers included in this special issue draw on policy sciences theories, concepts or methodological approaches and in our view this has led to a major enrichment of policy mix research within the field of science, technology and innovation (STI). The contributions in the special issue use a variety of qualitative and quantitative approaches to shed light on different dimensions of and research questions about policy mixes for sustainability transitions. This variety is encouraging and we hope that many scholars will build on these approaches in future analyses of policy mixes. In addition, all contributions in the special issue demonstrate the utility of their approaches in delivering insightful empirical analyses and propose avenues for further research. We hope that over time more analyses bridging innovation and policy studies will lead to a productive and systematic research programme on policy mixes for sustainability transitions that can provide valuable insights for policymaking.

We are convinced that thinking in terms of broader policy mixes, i.e. beyond instrument interactions as proposed in this special issue is relevant for policy makers, and in fact reflects much more their everyday experience compared to textbook assertions about "best" policy options. As such, policy mix research enables policy makers to advance their thinking about policy complexity, and provides a terminology and analytical tools to make sense of this complexity. For example, the contribution by Ossenbrink et al. enables policy makers to develop a bottom-up perspective from the angle of 'policy target groups' when their thinking may often be dominated by a top-down approach. The research of Ping and Edmondson et al. enables policy makers to adopt a more dynamic view of policy and its coevolution with important dynamics within the socio-technical systems. Another example is the proposed approach of Schmidt and Sewerin which allows policy makers to benchmark their policy approach with other countries and encourages them to (re-)assess the potential of 'layering' through policy patching as a realistic design strategy for more effective policy mixes.

In addition, several of the contributions also reflect on some of the political strategies to overcome challenges posed by path dependencies or power asymmetries or by diverging actor interests. For example, Dierks suggests strategies for overcoming sticking points within the OECD or for shifting the venue of decision making. The contribution by Ingold et al. reminds policy makers of the challenge of the (non)acceptance of policies by target groups and proposes to address it by providing more information to shape citizen preferences. Lindberg et al. emphasise the importance of adjusting the policy mix in line with technological developments, with the next logical step being to identify how this could be achieved given the preferences of dominant industry actors which they map. A final example is provided by Edmondson et al. who comment on the need to complement incentives for niche actors with support also for powerful (regime) actors in order to enable positive policy feedbacks required for maintaining momentum.

In summary, we argue that the policy mix literature is mainly of value to policy makers in terms of providing a heuristic or meta perspective on policy making as an ongoing, complex learning process and in highlighting some of the political challenges and providing some advice on political strategies rather than clear-cut policy design suggestions, and thus complements more conventional policy analysis. Clearly, there is still much to be learned from actual policy experiences about the way horizontal and vertical policy mix dynamics unfold and shape outcomes, how the co-evolution of the socio-technical system and policy influence policy outcomes, and how therefore policy mixes need to be adjusted over time to be able to foster socio-technical transitions. Making progress along these lines in terms of better understanding, but

more importantly through gaining practical experience of managing such complex and highly political processes needs to be a joint endeavour of scholars and policy makers interested in promoting sustainability transitions. We hope this special issue is providing a useful starting point for this journey.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.respol.2019.103832.

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